The Metallographic Study of Corrosion of Metals and Alloys by Crude Turpentine Gum and Related Substances

A Thesis

Submitted in Partial Fulfillment

of the Requirements for the

Degree of Master of Science

in

Chemical Engineering

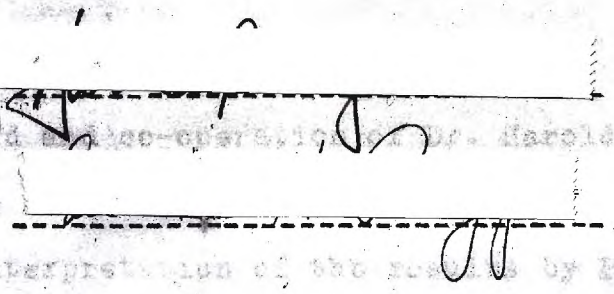
Submitted by

W. John Sloan

Georgia School of Technology

1933

Approved by



Acknowledgments

The writer wishes to acknowledge:

The aid and co-operation of Dr. Harold Bunger who directed the line of investigation;

The interpretation of the results by Professor Robert W. Sandelin;

The aid of J. A. Stokes, Jr. in the determination of pH values.

Abstract

The corrosive properties of slash pine gum, gum and its water mixtures, steam turpentine distillation vapors, and the distillation water layer were studied. The latter two are the most corrosive..Corrosion tests were run on iron, plain carbon steels, alloy steels, on copper, and on a copper alloy. Copper was readily corroded by the water layer, but the copper alloy was not affected by any of the above reagents. Ferrite, free, or in martensitic or pearlitic structures, was readily attacked. The nickel content of nickel-chromium steels,with the ratio of nickel to chromium a constant, does not appreciably affect the corrosion resistance. The structure most desired is austenitic. Best corrosion resisting results were obtained with a chrome steel-with small amounts of Mn and Si.

Georgia is the leading naval stores producing state of the Union ---its products were valued at $23,000,000 in 1930 (1). This industry has not had the benefit of extensive research, especially is this true regarding the study of the characteristics of crude turpentine gum. The object of this investigation was to study the corrosive properties of crude turpentine gum and related substances, and to determine the feasibility of studying this corrosion metallographically.

Very little information was found in the available literature. Turpentine which is distilled from iron retorts, or is stored in iron or tin containers, is darkened in color (2,3,4,5). The first runnings of turpentine, especially when a still is first used after a period of idleness, are colored green by copper salts (6). Turpentine gum collecting-cups which are often made of galvanized iron, rust rapidly if the galvanized surface is broken.

(1) 1930 Georgia Year Book of Agriculture, Ga. Dept. of Agriculture
(2) U. S. Dept. of Agriculture, Bulletin No. 898; 3-5 (1920)
(3) Thorpe's "Dictionary of Applied Chemistry". Vol. VII, 247 (1927)
(4) Chem. Abstr. 23;2565[1]
(5) Schorger and Betts, U. S. Dept. of Agriculture, Bulletin No. 229; 31 (1915)
(6) Ibid; 3

Preparation of Samples for polishing

Through the courtesy of about thirty concerns, the Division of Chemical Engineering and Metallurgy, Chemistry Department, Georgia School of Technology, was supplied with approximately one hundred different metals and alloys. These samples were properly numbered and a card index was made containing the necessary information about the samples. In all cases, unless otherwise noted, the analysis of each sample was given by the concern or individual supplying it.

The samples used in the corrosion tests were carefully prepared because the strains resulting from cutting or grinding, accelerate corrosion. Selected samples were cut into one inch squares or into convenient shapes. Whenever a sample was too thick to shear, or buckled when clamped in the saw vice, it was clamped to a board by means of "D" clamps and then placed in the saw vice.

Polishing of Samples

The method of polishing deviated somewhat from the customary procedure. "Alundum" which was used as the abrasive on a fast turning wheel, permitted quicker and better polishing. Optical rouge gave better results than ordinary polishing rouge.

A fast speed felt-covered polishing wheel gave good results, especially when the felt was lubricated with soap (7). Samples which could not be held by hand were either cemented to a stick or held in a clamp.

Etching of Sample

The first attempt at etching was made by placing a polished sample in the crude gum (8). This method yielded good results and was followed in the case of almost every sample. Polished samples were placed in the distillation flask during a steam turpentine distillation. One sample was placed in the hot gum and water mixture; another sample, usually of the same metal, was suspended in the distillation vapors by a holder made from a glass rod. This method also yielded good results but was troublesome and required close attention. The sample in the vapor was always etched the more and etched quickly. Observation of the etching process on several samples indicated that the vapors which came over first were probably the most corrosive.

(7) W. J. Sloan: Note on Polishing of Samples; Photographing; and the Development of Photographic Films. Copy in files of Metallurgy Division, Chemistry Department Ga. Tech.

(8) Slash pine gum from trees near Bronson, Levy County, Fla.

The water layer of the turpentine distillation was used as an etching reagent because of its acidity and because it contained part or all of the above corrosive vapors.

After a sample was suitably etched, it was examined under a microscope, and was photographed.

Discussion of Results

Corrosion tests were run on "Armco" iron, plain carbon steels, several alloy steels, on copper, and on a copper alloy.

The data for "Armco" iron, 55-1 and 55-2, point out two facts which are confirmed by the study of the plain carbon steels: namely, that the crude pine gum is a good etching reagent and produces an uniform etch; and that the water layer of a turpentine distillation acts as a free acid, such as hydrochloric, and has a pitting action. The relatively slow etching time of the gum and the uniformity of the etch indicate that it is not as destructive as the water layer. These facts are well shown by G 4 (3/27/33). G 17 (3/13/33-3/37/33) G 14 (3/10/33) and by S.A.E. 1095, 2-73 (4/27/33).

The data for the plain carbon steels indicate that an increase in carbon content means an increase in corrosion resistance, although the increasing darkness of the etch, due to the pearlitic areas, deceptively indicates the opposite. The presence of water in the gum increases the etching qualities. The hot gum and water

mixture of a distillation, when used as an etching reagent, showed the characteristics of a free acid. Pitting is general, and selective etching is sometimes evident. (See G 4, 3/13/33; G 14, 3/1/33; and G 17, 3/3/33). A temperature increase, besides having the usual effect of accelerating corrosion, probably causes the formation of corrosive agents within the gum. The distillation vapors seem to be the most corrosive of the reagents tested. A comparison of the effects of the distillation vapors and water layers shows that the corrosive agents are essentially the same. (See G 17, 3/10/33; and G 17, 3/13/33). We might conclude that all plain carbon steels having any free ferrite present will be corroded by the gum and by any water mixture or distillate.

Normally we would not expect copper to be corroded, but at a high temperature and in the presence of the organic acids of the water layer, it is probably oxidized, and then etched by the acids (See 12, 4/18/33). A copper alloy, 26-3 (88.5%Cu, 5.0% Ni, 5.0% Sn, and 1.5% Si), successfully resisted the etching of both the water layer and the gum.

This is not a complete study of the stainless steels, but enough data are available to show the relative corrosion resistance and probable causes. The results indicate that as long as we have an austenitic structure (typical of a stainless steel) and the ratio of nickel to chromium remains constant, the same

corrosion resistance is offered. (also see 9)

The most important thing shown by the data is the indication that a corrosion resisting steel may be secured by alloying manganese and silicon, instead of nickel, with a chrome steel. Since nickel is expensive and the corrosion resisting qualities of the steels are not noticeably improved by the addition of it, the desired austenitic structure and resisting qualities may be obtained by the use of chromium which is relatively inexpensive. A good sample of the good corrosion resistance offered by this type of alloy is the data from sample 63 (16.25% Cr, 0.11% C, 0.73% Si, 0.019% S, 0.032% P and 0.52% Mn). This chrome steel successfully resisted twenty days of exposure to the crude gum, and seventy minutes of exposure to a water layer (pH 5.4 at 25°C., etching temperature approximately 99°C).

The solid solution type of alloy with an austenitic structure produced by chromium and small amounts of manganese and silicon should be used for further research. Since copper is now being used in construction of turpentine stills, some research should be done on the copper alloys.

(9) C. E. Branson; Chem 64-c Report Ga. Tech (1933)

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 4

Magnification X 500

ETCHING 3/3/33

Reagent Turpentine distillation vapor

Time 55 min.

Remarks Temp. 80°- 98°C pH(25°C water layer) 4.2

Mechanical Treatment

COMPOSITION

.12-.16 % C

..... % Mn

..... % Si

..... % P

..... % S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

3/4" Round plain commercial

Heat Treatment

Remarks

80 seconds exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; over-exposure, under-development; Eastman D-29 developing solution; Eastman's acid fixing powders.

Sample suspended in vapor of turpentine distillation. Brown coloration formed on surface after about five minutes exposure. Rusty coloration readily removed with gasoline or alcohol.

Pearlitic areas shown.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 4

Magnification X 500

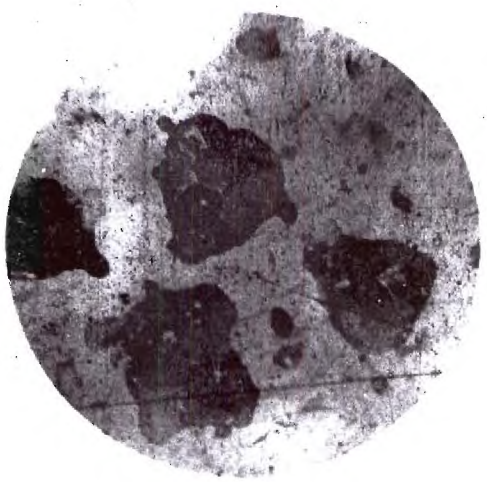
ETCHING 3/10/33

Reagent Water and slash pine gum

Time 1 1/2 hrs.

Remarks

Temp. approx. 100°C
Slight etch



COMPOSITION

.12-.16 % C

..... % Mn

..... % Si

..... % P

..... % S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

Mechanical Treatment

3/4" Round plain commercial

Heat Treatment

Remarks

80 seconds exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powder; reduced with R-4; stained by poor grade chemicals.

Sample etched in boiling gum and water mixture of turpentine distillation. No convenient control over corrosion.

Magnification too great for general view. Pearlite attacked; ferrite attacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 4

Magnification X 500

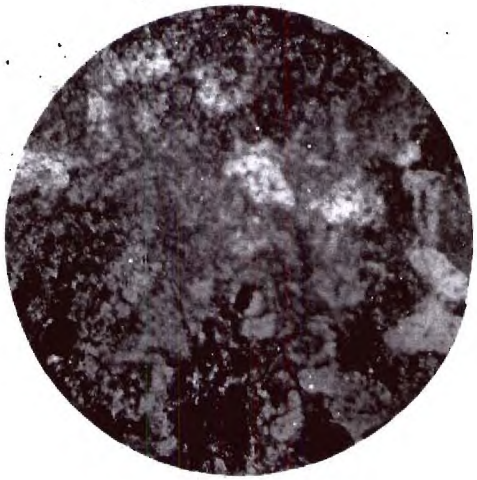
ETCHING 3/13/33

Reagent Distillation water layer

Time 48 hrs.

Remarks Temp. approx. 22°C Etched in darkness Over-etched. Soln tinted yellow

Mechanical Treatment $pH_{25°C}$ 3.1



COMPOSITION

.12-.16 % C

..... % Mn

..... % Si

..... % P

..... % S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

3/4" Round plain commercial

Heat Treatment

Remarks

80 seconds exposure, E. K. Co. Ortho Commercial film, Wratten B Filter No. 58; carbon arc; over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powder.

Magnification too great for general view. Pearlite areas attacked; ferrite unattacked.

Visual microscopic examination showed sample was covered uniformly with small pits. Corrosion uniform; reddish-brown in color.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 4

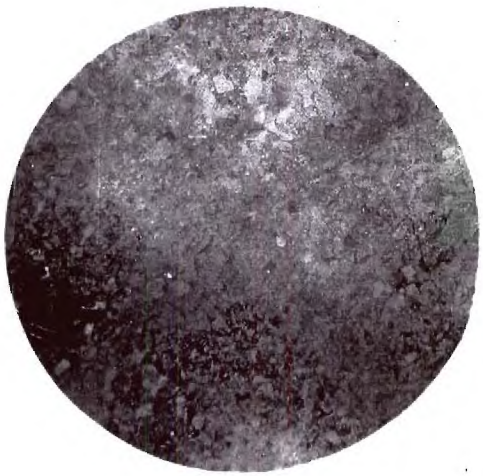
Magnification X 100

ETCHING 3/27/33

Reagent Slash pine gum

Time 21 hrs.

Remarks
Temp. approx. 20°C
Etched in darkness
Over-etched.



COMPOSITION

.12-.16 % C

..... % Mn

..... % Si

..... % P

..... % S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

Mechanical Treatment

3/4" Round plain commercial

Heat Treatment

Remarks

80 seconds exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powders; reduced slightly with R-4 Eastman)

Rusty streak formed at conjunction of air, gum and sample. Visual microscopic examination showed uniform etch.

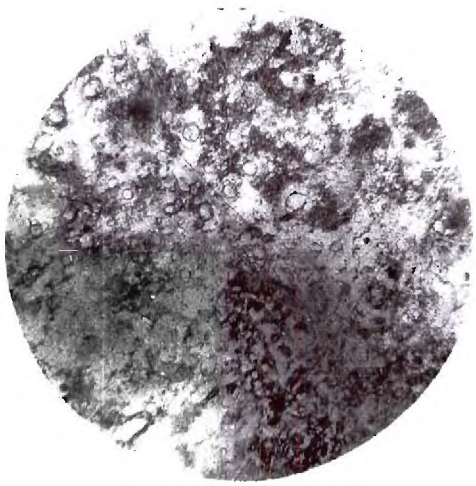
Pearlite attacked; ferrite attacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY
DEPARTMENT OF CHEMISTRY
DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel
Source Gulf States Steel Co.
Sample File 8 8
Magnification X 500



ETCHING 3/1/33
Reagent Turpentine distillation vapor
Time 55 min.
Remarks
Temp. approx. 99°C
Over-etched
pH(25°C water layer) 3.5
Mechanical Treatment
Either-
3/4" Round plain threading quality
or
3/4" Round plain structural
Identification numbering system not made clear by numberer.
Heat Treatment

COMPOSITION
.15-.20% C
.....% Mn
.....% Si
.....% P
.....% S
.....%.....
.....%.....
.....%.....
.....%.....
.....%.....

Remarks
Sample suspended by bent glass rod in hot vapor during a turpentine distillation.

80 seconds exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 98; over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powders.

Sample over-etched. Pearlite attacked; ferrite attacked.

Information by
W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 8

Magnification X 500

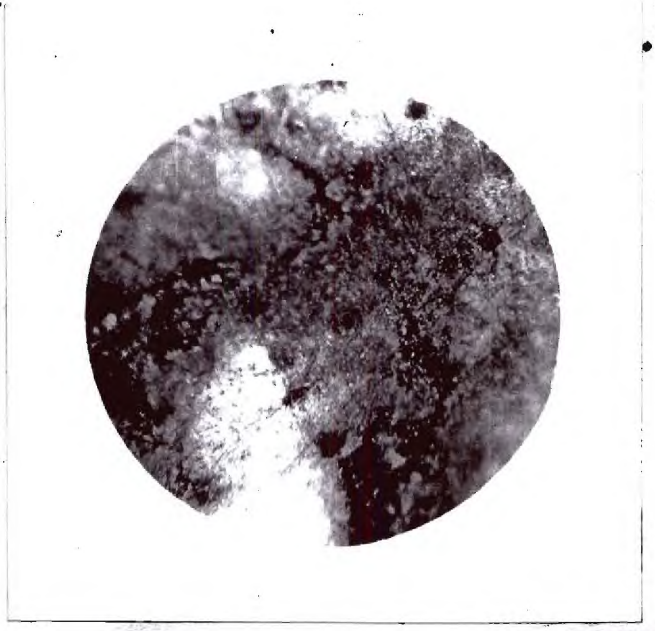
ETCHING 3/9/33
3/10/33

Reagent Distillation water layer

Time 20 min. 8 min.

Remarks Temp. 79 - 83° C
Temp. 80 - 95 C
pH (25° C) 3.7

Mechanical Treatment



COMPOSITION

.15-.20% C

.....% Mn

.....% Si

.....% P

.....% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

Either-
3/4" Round plain threading quality
Or- 3/4" Round plain structural
Identification numbering system not made clear by numberer.

Heat Treatment

Remarks Sample submerged in water layer. Etched 20 min. 3/9/33, 79-83° C., and 8 min. 3/10/33, 80-95° C. Over-etched for metallographic detail; at lower temperatures, slow etching; rapid etching at high temperatures. Rapid etching at edges of drops on polished surface when removed from hot liquid to air.

80 sec. exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; Eastman developer solution D-29; Eastman's acid fixing powders. Enlargement too great; not enough general view.

Visual microscopic examination showed no small etched spots. Even etch; slightly over-etched. Pearlite attacked; ferrite unattacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Deoxidized Copper

Source American Brass Co.

Sample File 12

Magnification X 100

ETCHING 4/18/33

Reagent Distillation water layer

Time 60 min.

Remarks
Temp. approx. 100°C
pH(25°C.) 5.2

COMPOSITION

..... % C

..... % Mn

..... % Si

.017 % P

..... % S

99.941 % Cu & Ag

..... %

..... %

..... %

..... %

Mechanical Treatment

Sample from flat sheet

Heat Treatment

Remarks

1 sec. exposure, E.K.Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; slight under-development; Eastman developer D-28; Eastman acid hardener stock solution F-1a.

Sample thin sheet; easily scratched; hard to polish; sample cemented to a stick by "Permatex" for handling while polishing.

Uniform etch without regard to structure; not deep; readily visible; brown colored, darker than copper; easily removed by touching to rotating felt wheel.

Information by

W. John Sloan

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 14

Magnification X 500

ETCHING 3/1/33

Reagent Water and slash pine gum

Time 55 min.

Remarks Temp. approx. 98°C.

COMPOSITION

.3-.4% C

.....% Mn

.....% Si

.....% P

.....% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

Mechanical Treatment

1" Round deformed intermediate

Heat Treatment

Remarks

80 seconds exposure; E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; Eastman D-29 developing soln; Eastman's acid fixing powders; over-exposure and under-development.

Sample placed in boiling gum and water during a turpentine distillation. Slightly over-etched but no convenient control over etching.

Pearlite attacked; ferrite attacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 14

Magnification X 100

ETCHING 3/10/33

Reagent Distillation water layer

Time 30 min.

Remarks Temp. 80°- 90°C

pH(25°C water layer) 3.7

Mechanical Treatment

COMPOSITION

.3-.4% C

.....% Mn

.....% Si

.....% P

.....% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

1" Round deformed intermediate

Heat Treatment

Remarks

80 seconds exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; Eastman D-29 developing solution; Eastman's acid fixing powders; over-exposure, under-development.

Sample submerged in water layer and heated.

Evenly etched; corrosion spots formed patterns; some pin spots noticeable. Pearlite attacked; ferrite attacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY
DEPARTMENT OF CHEMISTRY
DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 17

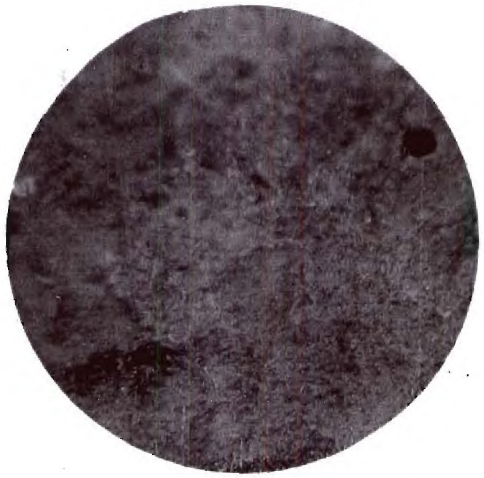
Magnification X 500

ETCHING 3/3/33

Reagent Water and slash pine gum

Time 55 min.

Remarks
Temp. approx. 99°C



COMPOSITION

.4-.5 % C
..... % Mn
..... % Si
..... % P
..... % S
.....%.....
.....%.....
.....%.....
.....%.....
.....%.....

Mechanical Treatment

1/2" Round, deformed rail steel equiv.

Heat Treatment

Remarks

80 seconds exposure, E. K. Co. Ortho Nitrate film; carbon arc; Wratten B Filter No. 98; over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powders.

Sample placed in water gum mixture during a turpentine distillation. Slightly over-etched.

Pearlite attacked; ferrite not attacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source ... Gulf States

..... Steel Co. ....

Sample File .. G 17 .....

.....

Magnification . X 500 .....

.....

ETCHING 3/10/33

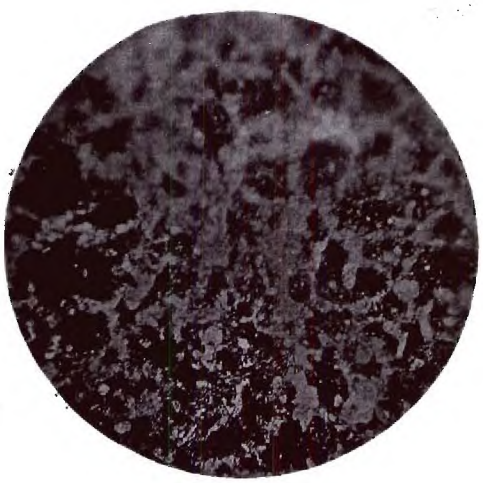
Reagent Turpentine distillation vapor

Time 1 1/2 hrs.

Remarks Temp. 80° - 100°C

pH(25°C water layer) 3.7

Mechanical Treatment



COMPOSITION

.4-.5 % C

..... % Mn

..... % Si

..... % P

..... % S

..... %.....

..... %.....

..... %.....

..... %.....

..... %.....

1/2" Round, deformed rail steel equiv.

Heat Treatment

Remarks

80 seconds exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powders.

Sample suspended in vapor of turpentine distillation. Discolored in a very short time. Slightly over-etched.

Pearlite attacked; ferrite ~~un~~attacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY
DEPARTMENT OF CHEMISTRY
DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 17

Magnification X 500

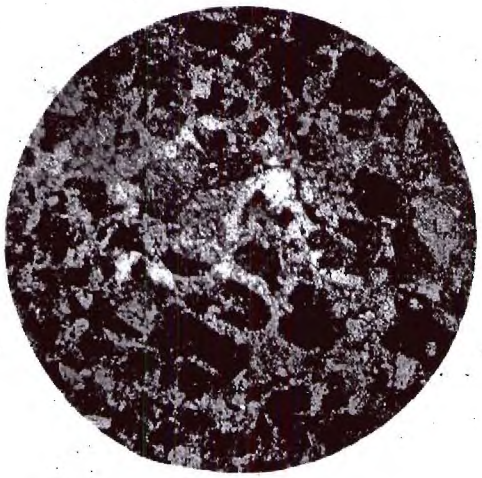
ETCHING 3/13/33

Reagent Distillation water layer

Time 48 hrs.

Remarks Temp. approx. 22°C
pH(25°C water layer) 3.7
Etched in darkness

Mechanical Treatment



COMPOSITION

.4-.5% C
.....% Mn
.....% Si
.....% P
.....% S
.....%.....
.....%.....
.....%.....
.....%.....
.....%.....

1/2" Round, deformed rail steel equiv.

Heat Treatment

Remarks

80 Seconds exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powders;

Sample submerged in a portion of water layer and placed in darkness. No discoloration of water layer. Visual microscopic examination shows patterns built up from small pin corrosion points. Corroded spots nearly round; reddish-brown in color; corrosion uniform except for pin spots.

Pearlite attacked; ferrite unattacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 17

Magnification X 100

ETCHING 3/27/33

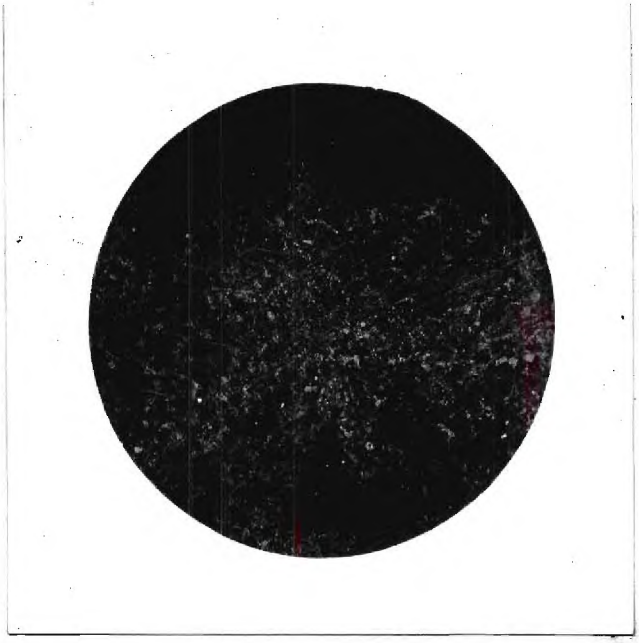
Reagent Slash pine gum

Time 21 hrs.

Remarks

Temp. approx. 20°C

Etched in darkness



COMPOSITION

.4-.5% C

.....% Mn

.....% Si

.....% P

.....% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

Mechanical Treatment

1/2" Round, deformed rail steel equiv.

Heat Treatment

Remarks

80 seconds exposure, Agfa Super-sensitive Plenachrome film; carbon arc; Wratten B Filter No. 58; over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powders.

One-half of sample submerged in pine gum. Rusty streak formed at conjunction of air, gum and metal. Visual microscopic examination shows gradual change from etched to unetched portion. Even etch.

Pearlite attacked; ferrite unattacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 17

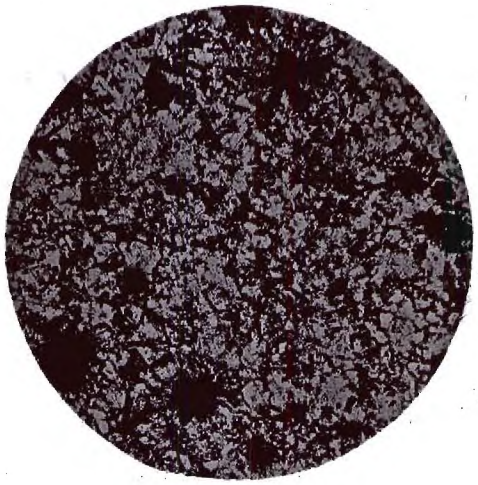
Magnification X 100

ETCHING 4/27/33

Reagent Slash pine gum

Time 20 3/4 hrs.

Remarks Temp. approx. 20°C
Slight etch
Etched in darkness



COMPOSITION

.40-.50% C

.....% Mn

.....% Si

.....% P

.....% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

Mechanical Treatment

1/2" Round, deformed rail steel equiv.

Heat Treatment

Remarks

1 second exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; slight under-development. Developing soln. Eastman's D-28; Eastman's acid hardener stock soln. F-1a.

Visual microscopic examination shows etch started in spots and spread. Pearlite attacked; ferrite unattacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source Gulf States Steel Co.

Sample File G 17

Magnification X 100

ETCHING 4/28/33

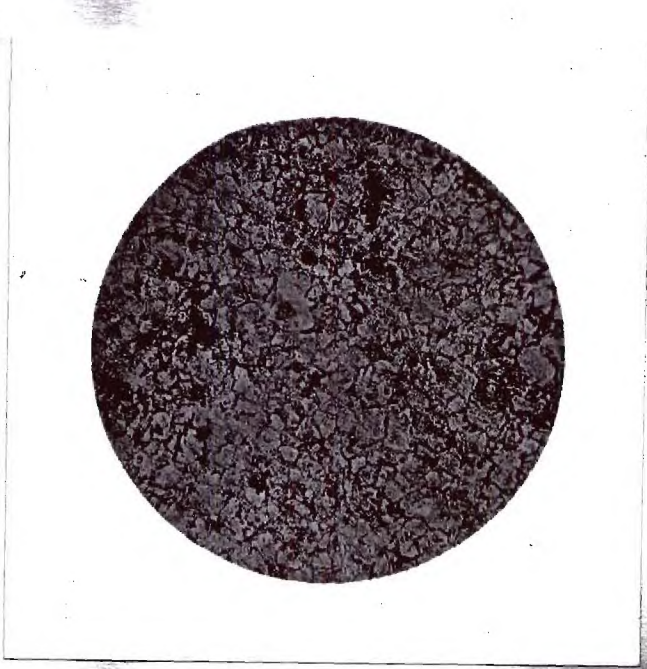
Reagent Distillation water layer

Time 9 min.

Remarks Temp. 100°C

ph(25°C water layer) 6.2

Mechanical Treatment



COMPOSITION

.4-.5% C

.....% Mn

.....% Si

.....% P

.....% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

1/2" Round, deformed rail steel equiv.

Heat Treatment

Remarks

1 sec. exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; slight under-development; Eastman D-28 developing solution; Eastman acid hardener stock solution F-1a.

Sample placed in water layer and heated. Visual microscopic examination shows even distinct etch.

Pearlite areas attacked; ferrite distinct, attacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Stainless Steel

Source Colonial Steel Co.

Sample File 47-2

Magnification X 100

ETCHING 4/6/33

Reagent Slash pine gum

Time 20 days

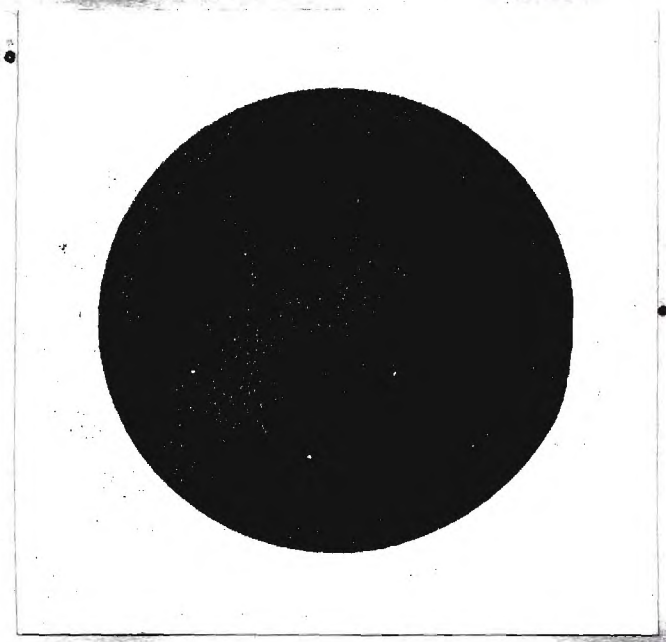
Remarks

Temp. approx. 20°C

Etched in darkness

Mechanical Treatment

Rolled strip



COMPOSITION

.10% C

.40% Mn

.27% Si

.016% P

.017% S

13.17% Cr

.....%.....

.....%.....

.....%.....

.....%.....

Heat Treatment

Annealed

Remarks

1 sec. exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; Eastman developer D-88; Eastman acid hardener stock solution F-1a; slight under-development.

Sample placed in gum and placed in the dark. Removed after two weeks and examined. Replaced in renewed gum for six more days.

Etch: light, uniform; slightly white in color; selective corrosion. Troostite(dark areas) attacked; the background, white martensite, unattacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY
DEPARTMENT OF CHEMISTRY
DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Armco Ingot Iron

Source American Rolling Co.

Sample File 55-1

Magnification X 100

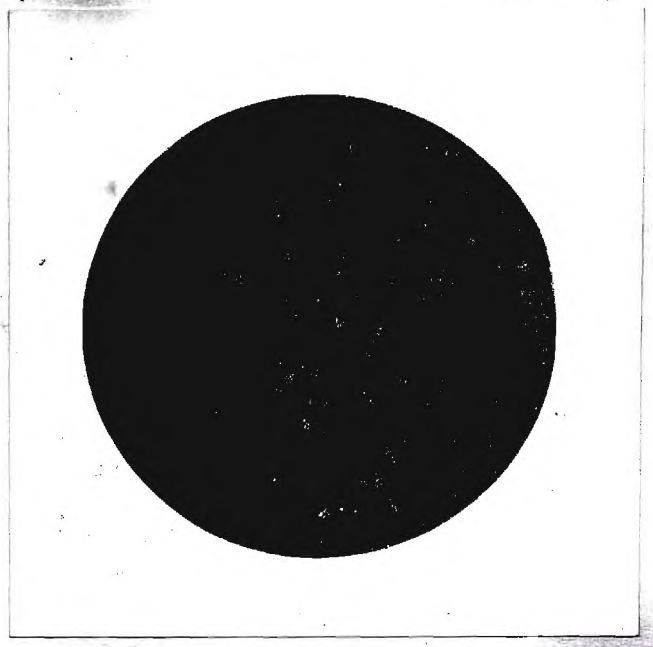
ETCHING 4/19/33

Reagent Slash pine gum

Time 45 hrs.

Remarks Temp. approx 21°C Etched in darkness

Mechanical Treatment Sample from a plate



Typical COMPOSITION

.018	% C
.018	% Mn
.003	% Si
.004	% P
.023	% S
	%
	%
	%
	%
	%

Heat Treatment

Remarks 1 sec. exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; Eastman D-28 developing solution; Eastman acid hardener stock solution F-1a; slight under-exposure.

Sample submerged in pine gum and placed in darkness. Examination showed uniform corrosion; some pits; no corrosion evident along grain boundaries; etch was so even examinations during etching did not show any well defined structure. Sample shows some hard spots.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Armco Ingot Iron

Source American Rolling Co.

Sample File 55-2

Magnification X 100

ETCHING 4/25/33

Reagent Distillation water layer

Time 35 min.

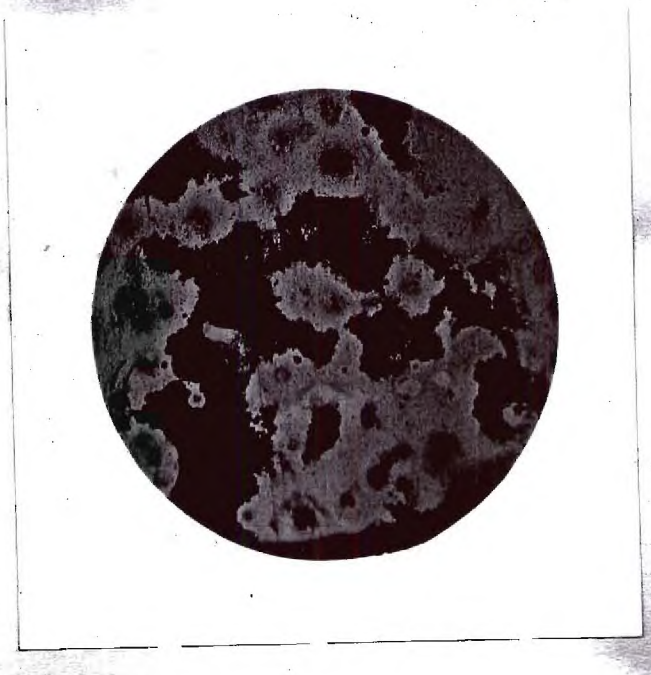
Remarks

Temp. approx. 99°C

pH(25°C water layer) 4.6

Mechanical Treatment

Sample from a plate



COMPOSITION

.012% C

.018% Mn

.003% Si

.004% P

.023% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

Heat Treatment

Remarks

1 sec. exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; slight under-exposure; Eastman developer D-28; Eastman acid hardener stock slon. F-1a.

Sample placed in the water layer of a turpentine distillation and heated. Examination shows a somewhat selective etch. Selected areas visible to naked eye. Corroded areas well scattered; are without any general shape, and appear to be the result of spreading corrosion.

Information by

W. John Slaon.

GEORGIA SCHOOL OF TECHNOLOGY
DEPARTMENT OF CHEMISTRY
DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Heat Resisting Steel

Source Chicago Steel Foundry Co.

Sample File 56

Magnification X 100

ETCHING 4/26/33

Reagent Distillation water layer

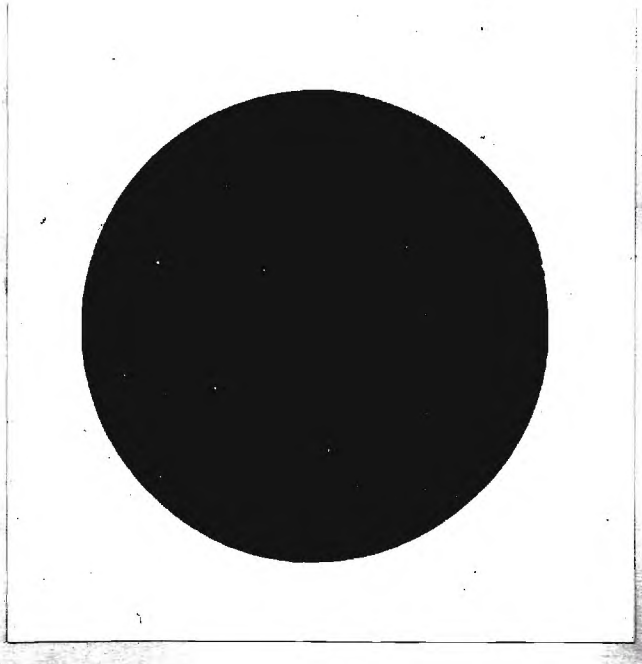
Time 2 1/3 hrs.

Remarks

Temp. approx. 99°C
pH(25°C. water layer) 5.5

Mechanical Treatment

Machined from casting



COMPOSITION

.....5% C
.....% Mn
2.5-3% Si
.....% P
.....% S
.....35% Cr Max.
.....20% Ni Max.
.....%.....
.....%.....
.....%.....

Heat Treatment

Remarks

1 sec. exposure, E. K. Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; under-exposure, under-development; Eastman developer D-88; Eastman acid hardener stock solution F-1a.

Sample heated (approx. 99°C.) in water layer (pH, 25°C, 4.8) on 4/20/33 for fifty-five minutes. Liquid was slightly discolored but there was no evidence of corrosion with the exception of a narrow streak.

Sample later etched by longer corrosion in turpentine distillation water layer. Examination shows an austenitic structure. Etched areas are pearlite in the grain boundaries. Even etch. Hard spots grouped in clusters. Austenite not attacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Heat

Type Resistling Steel

Source Chicago Steel Foundry Co.

Sample File 58

Magnification X 100

ETCHING 4/26/33

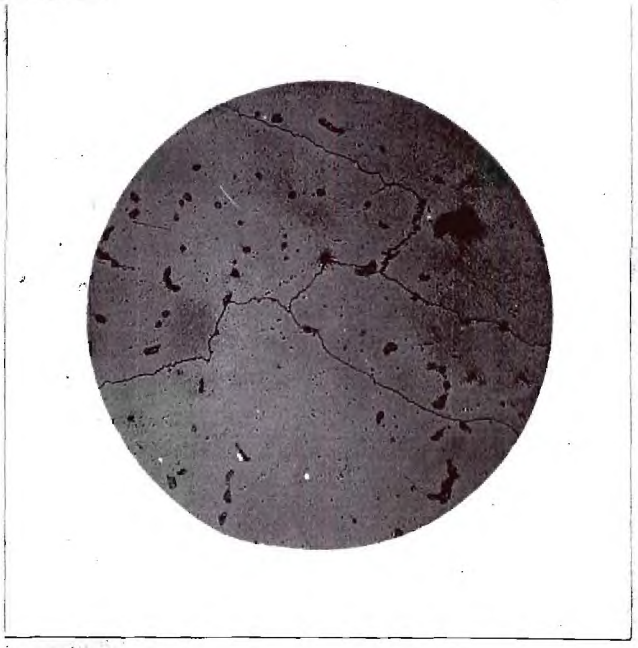
Reagent Distillation water layer

Time 80 min.

Remarks

Temp. approx. 99°C.
pH(water layer 25°C) 5.1

Mechanical Treatment



COMPOSITION

..... % C

..... % Mn

2.5-3 % Si

..... % P

..... % S

15 % Ni Approx

8 % Cr "

..... %

..... %

..... %

Machined from casting. Difficult to machine.

Heat Treatment

Remarks

Two negatives; for better one; 2.sec. exposure, E. K. Cō. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; slight under-exposure, and under-development; Eastman developer D-28, Eastman acid hardener F-1a.

Sample etched by placing in water layer and heating.

The etch was not as good as it should have been for a good negative. Etch not visible to naked eye. Visual Microscopic examination shows very distinct austenic structure. The pearlite in the grain boundaries was etched. Examination also shows the separation of iron carbide in a matrix of austenite. Some well scattered hard spots were present.

Information by

W. John Sloan

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source M.E. Dept. Ga. Tech

O. M. Harrelson

Sample File S.A.E.,

1095, 2

Magnification X 500

COMPOSITION

.9-1 % C

..... % Mn

..... % Si

..... % P

..... % S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

ETCHING 3/21/33

Reagent Distillation water layer

Time 45 min.

Remarks

Temp. approx. 98°C.
pH(water layer 25°C) 4.0

Mechanical Treatment

Round, hot rolled.

Heat Treatment

Remarks

This sample is a standard S.A.E. steel and the above identification was consistantly used on the negatives and in the data. Sample as originally received was numbered 2.

80 sec. exposure, E.K.Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; Over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powders.

Sample placed in turpentine distillation water layer and heated. Rapid etching. Over-etched.

Microscopic examination showed pearlitic structure attacked; even etch; many round hard spots which are probably spheroidized iron carbide. In the above picture the hard spots (white) are well shown. They were not etched and were above the plane level of the etched surface.

Information by

W. John Sloan

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source M.E.Dept.GaTech

O. M. Harrelson

Sample File S.A.E., 1095, 2

Magnification X 100

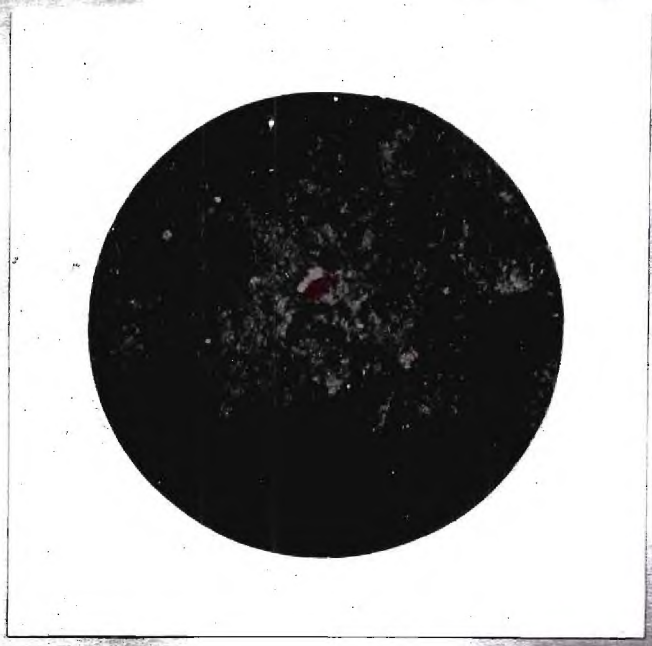
ETCHING 3/27/33

Reagent Crude turpentine gum

Time 21 hours

Remarks Temperture approx. 20°C. Etched in darkness.

Mechanical Treatment Hot rolled, round.



COMPOSITION

.9-1 % C

.....% Mn

.....% Si

.....% P

.....% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

Heat Treatment

Remarks

Sample, standard S.A.E. 1095 steel. Received marked 2.

80 sec. exposure, E.K.Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powders; attemped to reduce with Eastman R-4.

Sample partially submerged in gum; polished surface vertical.

Sample well, and evenly etched. Etch visible to naked eye; a misty-grey in color. Rusty streak at conjunction of air, gum and sample. Portion unsubmerged was very slightly etched. Sample over-etched.

Pearlitic areas are attacked.

Information by

W. John Sloan

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source M.E.Dept. Ga. Tech

O. M. Harrelson

Sample File S.A.E.,

1095, 2-44

Magnification X 100

ETCHING 5/1/33

Reagent Slash pine gum

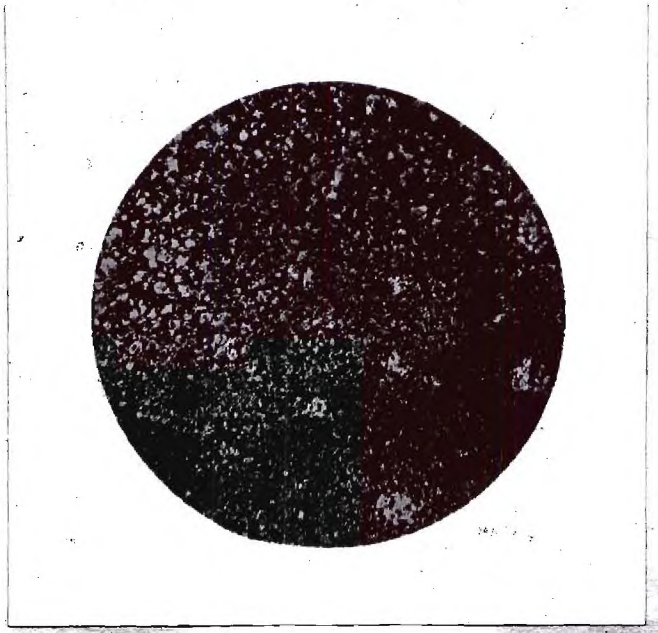
Time 3/4 hours

Remarks 49

Temperature approx. 20°C. Etched in darkness

Mechanical Treatment

Round, Hot rolled



COMPOSITION

.9-1 % C

.....% Mn

.....% Si

.....% P

.....% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

Heat Treatment

Heated then quenched to produce martensite.

Remarks

Sample, standard S.A.E. 1095 steel. Received numbered 2-44
2 sec. exposure, E.K.Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; slighily under-exposed; Eastman developer; D-28; Eastman acid hardener stock solution F-1a.
Sample submerged in crude gum. Etched slowly. Nice etch.

Martensite attacked.

Information by

W. John Sloan

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source M.E.Dept...Ga. Tech

...O...M...Harrelson.

Sample File S.A.E.,.....

...1095,...2-56.....

Magnification ..X..500.....

.....

ETCHING 3/21/33

Reagent Distillation water layer

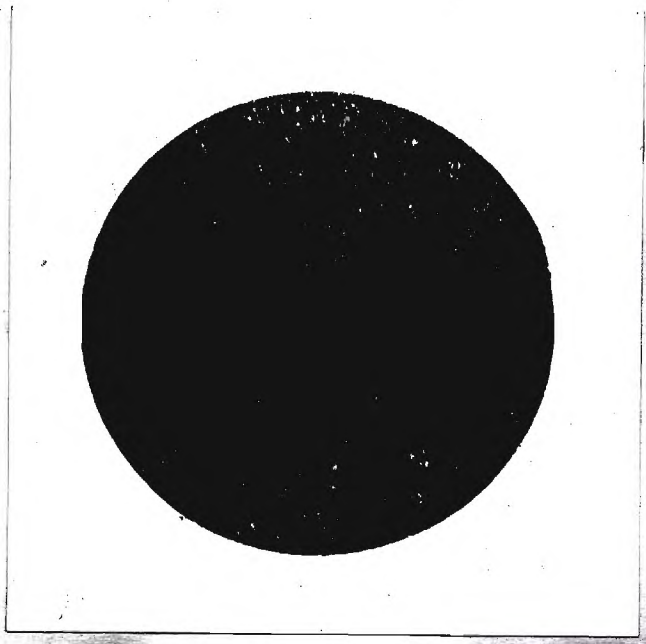
Time 15 min.

Remarks

Temp. 95°-99°C.

pH(water layer 25°C) 4.0

Mechanical Treatment



COMPOSITION

.9-1.% C

.....% Mn

.....% Si

.....% P

.....% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

Round, hot rolled

Heat Treatment

Heated then quenched to produce martensite.

Remarks

Sample, standard S.A.E. steel no. 1095. Received numbered 2-55.

80 sec. exposure, E.K.Co. Ortho Commercial film; Carbon arc; Wratten B Filter No. 58; Over-exposure, under-development; Eastman developer D-29; Eastman's acid fixing powders.

Sample placed in turpentine distillation water layer and heated. Slightly over-etched. Rapid etching.

Martensite attacked.

Information by

W. John Sloan

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source M.E.Dept., Ga. Tech

O. M. Harrelson

Sample File S.A.E., 1095, 2-56

Magnification X 100

ETCHING 5/3/33

Reagent Distillation water layer

Time 12 min

Remarks

Temp. approx. 98°C.
pH(water layer 25°C) 5.9

Mechanical Treatment

COMPOSITION

.9-1 % C

..... % Mn

..... % Si

..... % P

..... % S

..... %

..... %

..... %

..... %

..... %

Round, hot rolled.

Heat Treatment

Heated then quenched to produce martensite.

Remarks

Sample, standard S.A.E. 1095 steel. Received numbered 2-56.

1 sec. exposure, E.K.Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; slightly under-exposed; Eastman developer D-28; Eastman acid hardener stock solution F-1a.

Sample placed in hot water layer, polished surface vertical. Water layer slightly discolored. Rusty streak at conjunction of air, water layer and sample. Nicely etched.

Martensitic structure attacked.

Information by

W. John Sloan.

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source M.E.Dept. Ga. Tech
O. M. Harrelson

Sample File S.A.E.,
1095, 2-73

Magnification X 100

COMPOSITION

.9-1.% C
.....% Mn
.....% Si
.....% P
.....% S
.....%.....
.....%.....
.....%.....
.....%.....
.....%.....

ETCHING 4/20/33

Reagent Distillation water layer

Time 12 min

Remarks
Temp. 70°-75°C
pH(water layer25°C) 3.5

Mechanical Treatment

Round, hot rolled.

Heat Treatment

The sample had been heat treated and showed upon etching with picric acid that the prevailing structure was sorbitic with some pearlitic areas around the edges.

Remarks

Sample, Standard S.A.E. 1095 steel. Received marked 2-73
1 sec. exposure, E.K.Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; film under-exposed, under-developed; Eastman developer D-28; Eastman acid hardener stock solution F-1a.
Sample placed in hot water layer of turpentine distillation, polished surface vertical. Sample was quickly etched(note low pH) Over -etched.
Microscopic examination shows two types of corrosion. Large etched areas spread out from the hard spots in the metal. The latter seemed to be corrosion centers. The other type was small spots between the above etched areas. The picture is of a sorbitic area. The sorbite was attacked. The white areas are iron carbide.

Information by

W. John Sloan

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

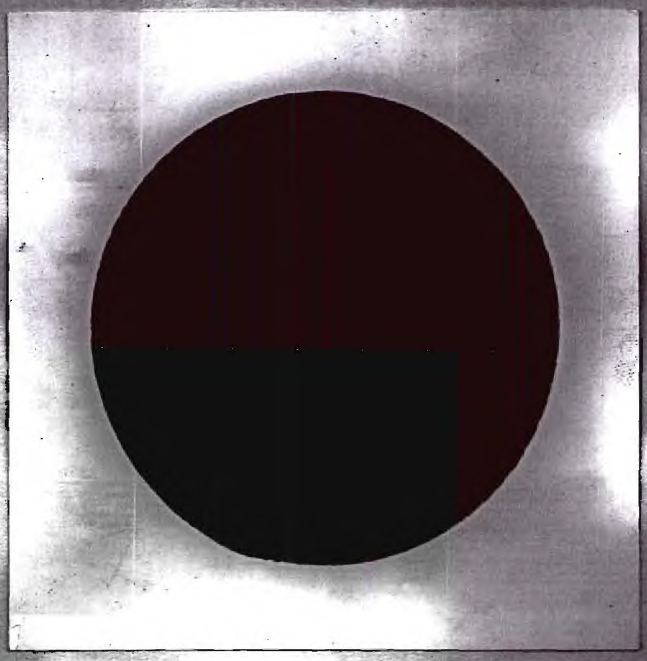
Source M.E.Dept. Ga. Tech

O.M. Harrelson

Sample File S.A.E.,

1095, 2-73

Magnification X 100



COMPOSITION

.9-1.0% C

.....% Mn

.....% Si

.....% P

.....% S

.....%.....

.....%.....

.....%.....

.....%.....

.....%.....

ETCHING 4/27/33

Reagent Slash pine gum

Time 20 3/4 hours

Remarks Temp. approx. 20°C. Etched in darkness

Mechanical Treatment

Round, hot rolled

Heat Treatment

The sample had been heat treated and showed upon etching with picric acid that the prevailing structure was sorbitic with some pearlitic areas around the edges.

Remarks

Sample, standard S.A.E. steel, no. 1095. Received numbered 2-73 1 sec. exposure. E.K.Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; Slightly under-exposed; Eastman developer D-28; Eastman acid hardener stock solution F-1a.

Sample submerged in crude gum overnight. Nicely etched.

Picture is of a pearlitic area. Pearlite attacked. The white areas of martensite unattacked. The darkest spots are hard areas.

Information by

W. John Sloan

GEORGIA SCHOOL OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

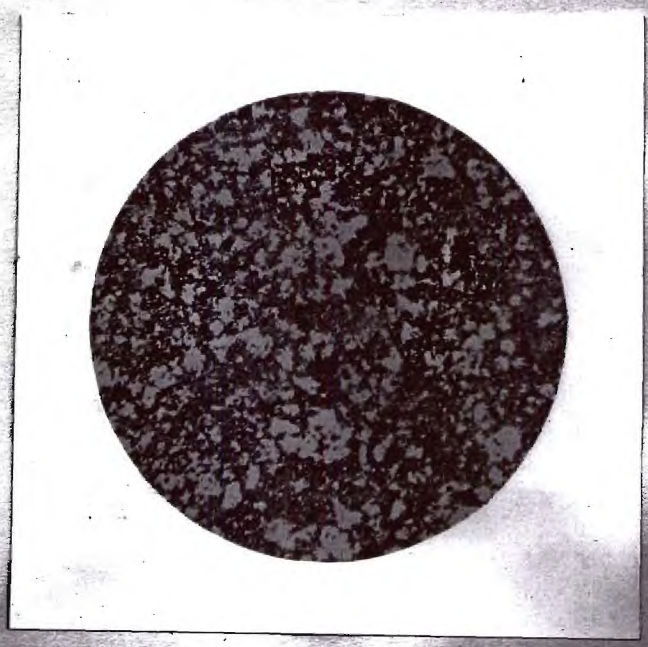
DIVISION OF CHEMICAL ENGINEERING AND METALLURGY

Type Plain Carbon Steel

Source M.E.Dept. Ga Tech
O.M. Harrelson

Sample File S.A.E., 1095, 2-73

Magnification X 100



COMPOSITION

.9-1.% C
.....% Mn
.....% Si
.....% P
.....% S
.....%.....
.....%.....
.....%.....
.....%.....
.....%.....

ETCHING 4/28/33

Reagent Distillation water layer

Time 6 min.

Remarks Temp. approx. 99°C.
pH(water layer 25°C) 6.3

Mechanical Treatment Round, hot rolled.

Heat Treatment

The sample had been heat treated and showed upon etching with picric acid that the prevailing structure was sorbitic with some pearlitic areas around the edges.

Remarks

Sample, standard S.A.E. steel, no. 1095. Received numbered 2-73.

1 sec. exposure, E.K.Co. Ortho Commercial film; carbon arc; Wratten B Filter No. 58; slighily under-exposed; Eastman developer D-28; Eastman acid hardener stock solution F-1a.

Picture is of a pearlitic area. Microscopic examination indicates that the etching was much like that of a free acid such as HCl. Pearlitic areas attacked. White areas are martensite.

Sample etched in turpentine distillation water layer.

Information by

W. John Sloan